US009840922B2

(12) **United States Patent**
Whitehurst

(10) **Patent No.: US 9,840,922 B2**
(45) **Date of Patent: Dec. 12, 2017**

(54) **FAN BLADE SPACER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 280 days.

(21) Appl. No.: **14/546,471**

(22) Filed: **Nov. 18, 2014**

(65) **Prior Publication Data**

US 2015/0252678 A1 Sep. 10, 2015

Related U.S. Application Data

(60) Provisional application No. 61/949,649, filed on Mar. 7, 2014.

(51) **Int. Cl.**

F01D 5/32	(2006.01)
F01D 5/30	(2006.01)
F01D 5/02	(2006.01)

(52) **U.S. Cl.**

CPC ***F01D 5/326*** (2013.01); ***F01D 5/02*** (2013.01); ***F01D 5/3092*** (2013.01); ***F01D 5/323*** (2013.01); *F05D 2220/32* (2013.01); *F05D 2220/36* (2013.01); *F05D 2230/70* (2013.01); *F05D 2230/72* (2013.01); *F05D 2230/80* (2013.01); *F05D 2240/30* (2013.01); *F05D 2250/281* (2013.01); *F05D 2300/501* (2013.01); *Y02T 50/672* (2013.01)

(58) **Field of Classification Search**

CPC F01D 5/02; F01D 5/22; F01D 5/30; F01D 5/3007; F01D 5/3023; F01D 5/3092; F01D 5/323; F01D 5/326; F01D 5/00; F01D 5/10; F01D 5/12; F01D 5/16; F01D 5/26; F05D 2220/32; F05D 2220/36; F05D 2230/70; F05D 2230/72; F05D 2230/80; F05D 2240/30; F05D 2250/281; F05D 2300/501

See application file for complete search history.

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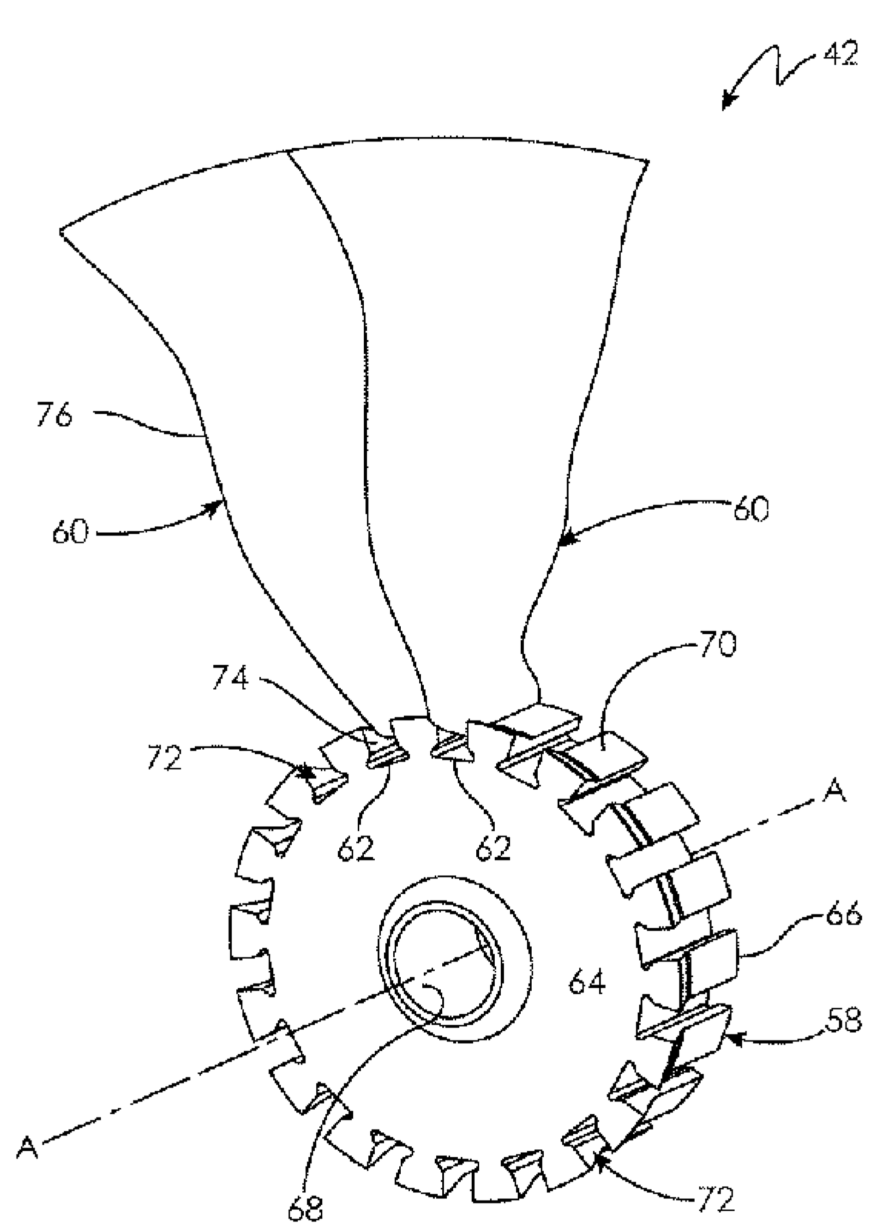
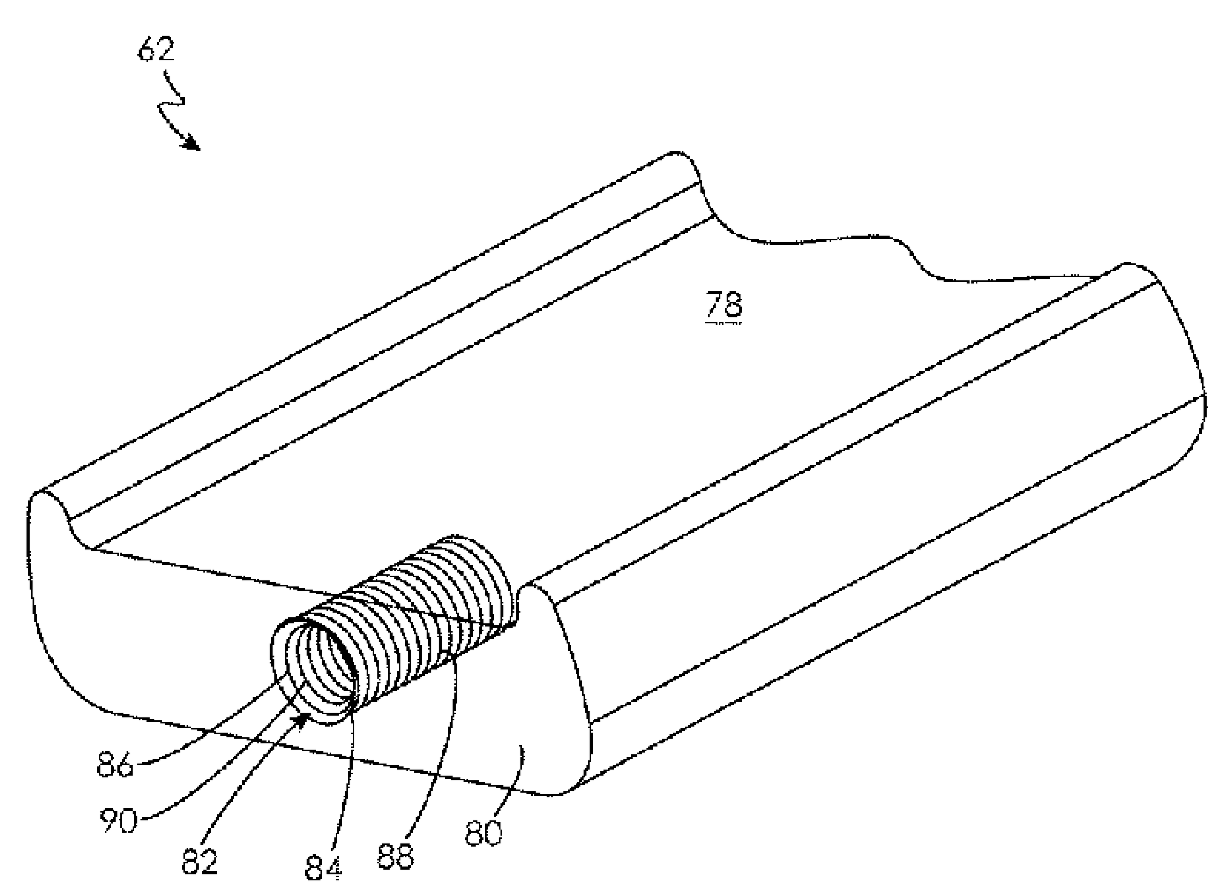
(57) **ABSTRACT**

The present disclosure relates generally to a fan blade spacer including a conduit disposed within a fan blade spacer composed of an elastically deformable material.

15 Claims, 3 Drawing Sheets





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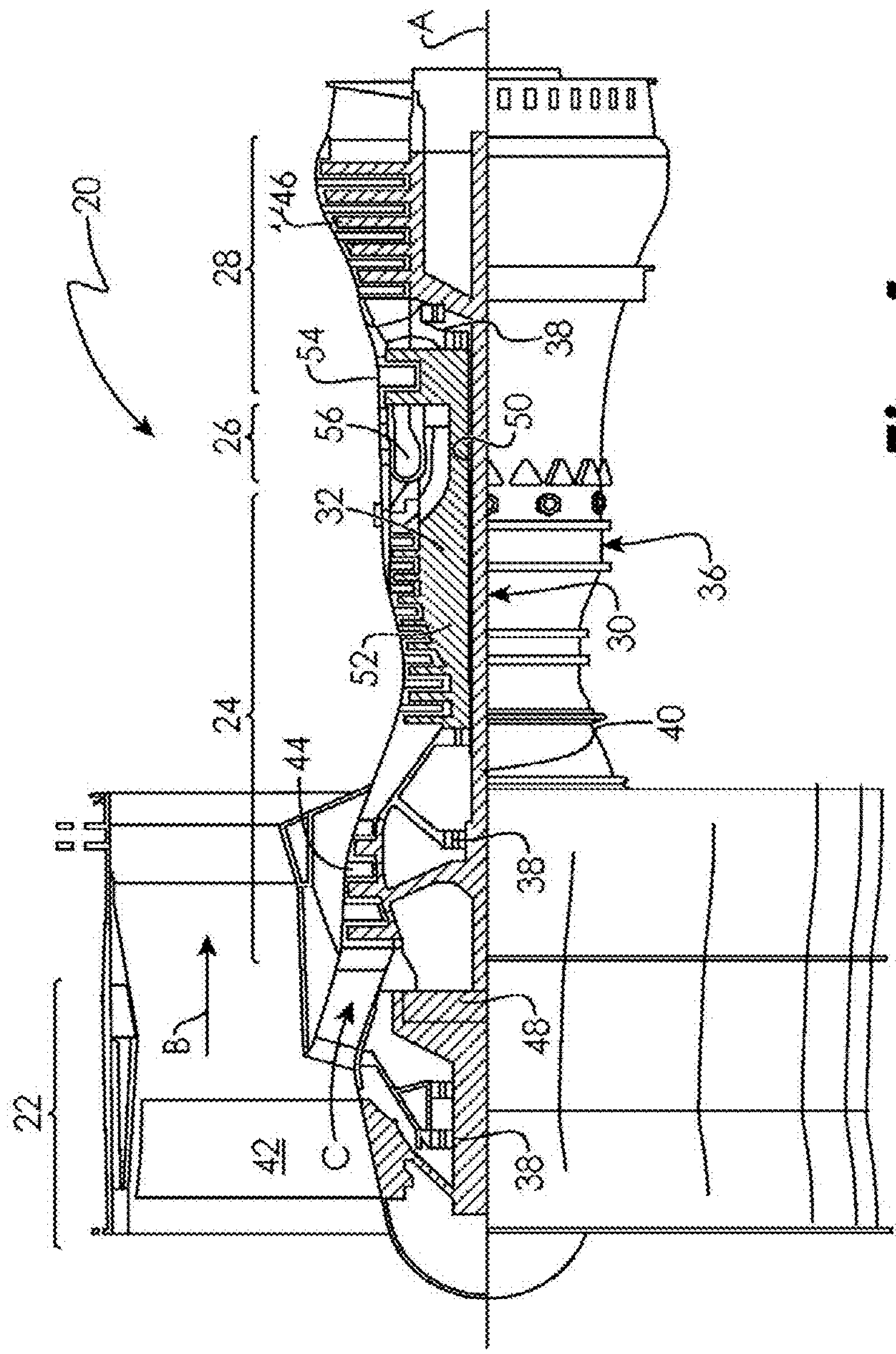

Fig. 1

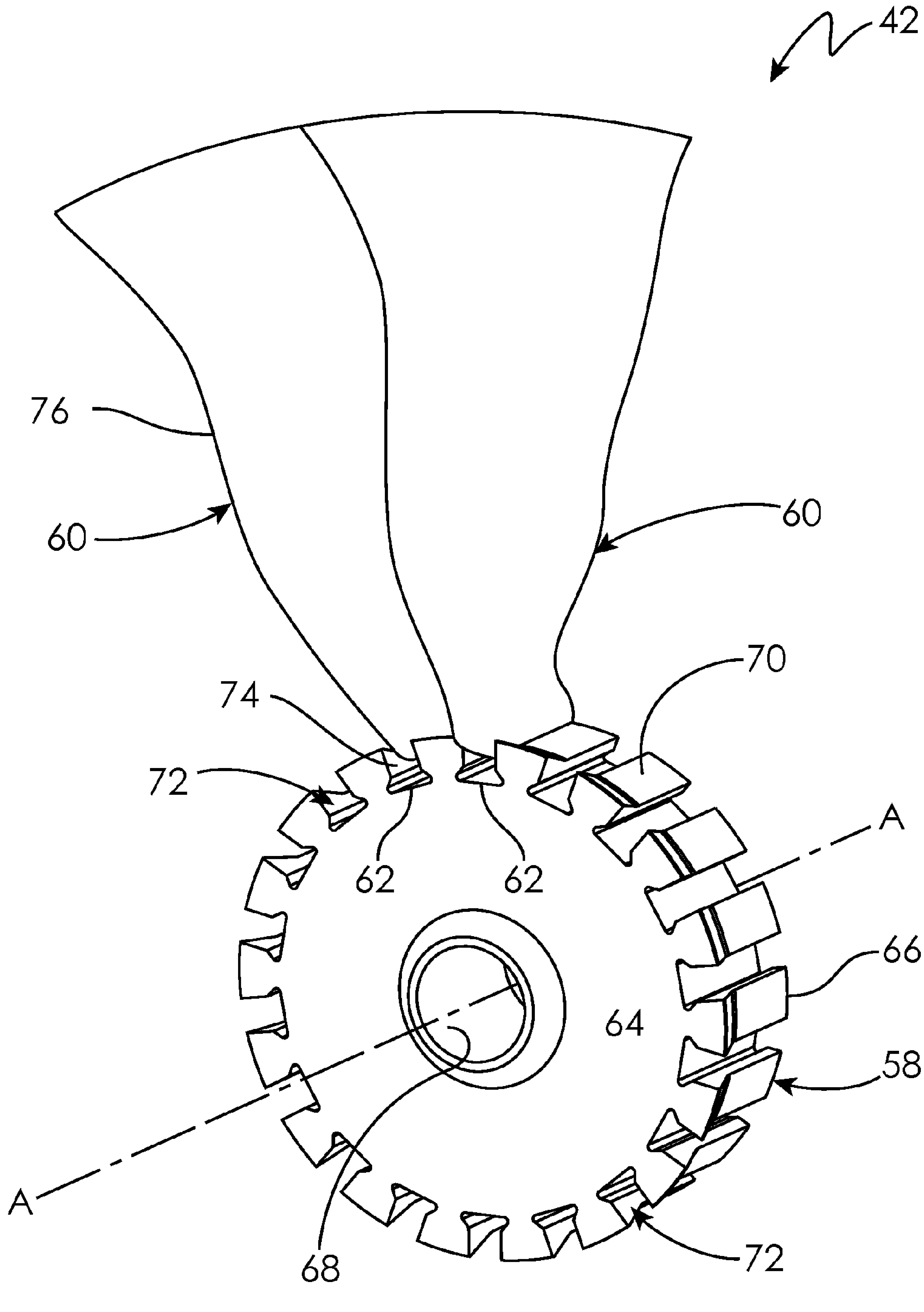

Fig. 2

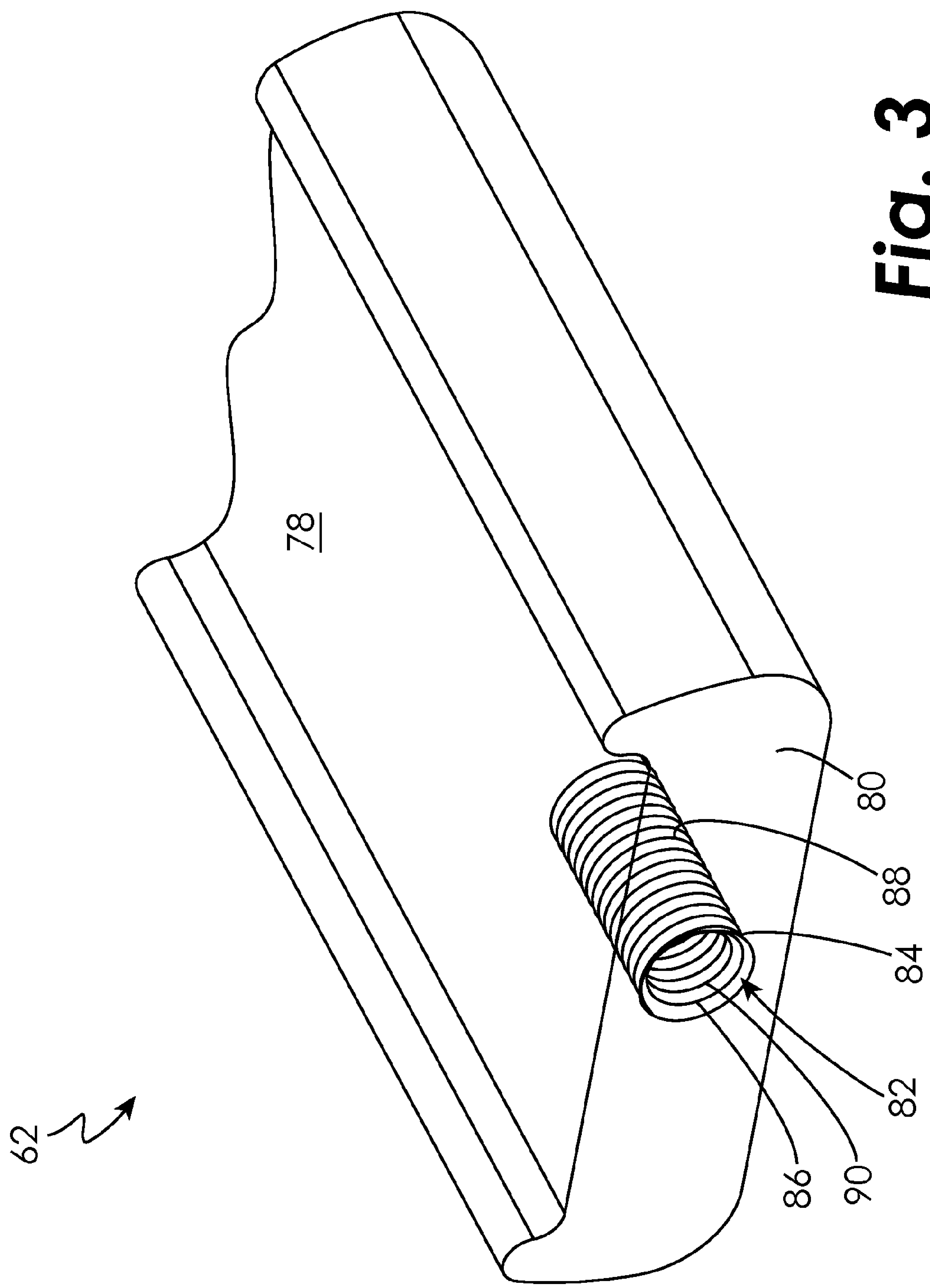

Fig. 3

FAN BLADE SPACER

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is related to, and claims the priority benefit of, U.S. Provisional Patent Application Ser. No. 61/949,649 filed Mar. 7, 2014, the contents of which are hereby incorporated in their entirety into the present disclosure.

TECHNICAL FIELD OF THE DISCLOSED EMBODIMENTS

The present invention relates generally to gas turbine engines and, in particular, to a fan assembly that includes one or more fan blade spacers.

BACKGROUND OF THE DISCLOSED EMBODIMENTS

A fan assembly for a typical gas turbine engine includes a plurality of fan blades arranged circumferentially around a rotor disk. Each fan blade may include an airfoil connected to a dovetail root, which is inserted into a respective dovetail slot within the rotor disk. The radial height of the root is typically less than the radial height of the slot. A gap therefore may be formed between a radial inner surface of the root and a radial inner surface of the slot. Such a gap is typically filled with a fan blade spacer.

A typical fan blade spacer reduces slippage and wear between the root and the slot during engine operation when, for example, centrifugal loading on the fan blade is relatively low (e.g., during wind milling). The fan blade spacer may be configured therefore to reduce (e.g., minimize) clearance within the gap that would otherwise be available for relative motion (e.g., pivoting) between the root and the slot. Generally, fan blade spacers are composed of heavy metals or non-durable plastic. The existing non-durable plastic spacers are usually machined to include a retrieval feature that can break during use; thus, requiring a new spacer to be installed.

Improvements in fan blade spacers are therefore needed in the art.

SUMMARY OF THE DISCLOSED EMBODIMENTS

In one aspect, a fan blade spacer is provided. Each spacer includes elongated body member including a first spacer end and a second spacer end. Each spacer may be constructed from an elastically deformable material. In at least one embodiment, the elastically deformable material is selected from a group consisting of: a rigid elastic material, a compliant material, an elastomeric material, a viscoelastic composite material, a plastically crushable material, a thermoplastic material, a thermoset material, and a honeycomb structured material.

Each spacer further includes a conduit, including a conduit outer surface and a conduit inner surface, disposed within the elongated body member. In at least one embodiment, the conduit is positioned near one of either the first spacer end or the second spacer end. In at least one embodiment, the conduit is composed of a metallic material. In at least one embodiment, the conduit includes a plurality of threads disposed on the conduit outer surface. In at least one embodiment, the conduit includes a plurality of threads disposed on the conduit inner surface. In at least one embodiment, the conduit is formed in a helical shape.

Other embodiments are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments and other features, advantages and disclosures contained herein, and the manner of attaining them, will become apparent and the present disclosure will be better understood by reference to the following description of various exemplary embodiments of the present disclosure taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a schematic cross-sectional view of a gas turbine engine;

FIG. **2** is a perspective illustration of a partially assembled fan assembly for a gas turbine engine; and

FIG. **3** is a perspective illustration of a spacer for use with a fan assembly.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of this disclosure is thereby intended.

FIG. **1** schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section **22** drives air along a bypass flow path B in a bypass duct, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.

The low speed spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a low pressure compressor **44** and a low pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a high pressure compressor **52** and high pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. An engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The engine static structure **36** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

The core airflow is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of combustor section **26** or even aft of turbine section **28**, and fan section **22** may be positioned forward or aft of the location of gear system **48**.

The engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the engine **20** bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture **48** is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine **46** has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine **20** bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **44**, and the low pressure turbine **46** has a pressure ratio that is greater than about five 5:1. Low pressure turbine **46** pressure ratio is pressure measured prior to inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet (10,688 meters). The flight condition of 0.8 Mach and 35,000 ft., with the engine at its best fuel consumption—also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC')"—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(\text{Tram } ^\circ \text{R})/(518.7^\circ \text{R})]^{0.5}$. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second (350.5 m/sec).

FIG. **2** illustrates a partially assembled fan assembly **42** for the gas turbine engine **20**. The fan assembly **42** includes a rotor disk **58**, a plurality of fan blades **60**, and a plurality of fan blade spacers **62**. The rotor disk **58** extends along the axial centerline A between a first disk end **64** and a second disk end **66**. The rotor disk **58** also extends radially from an inner disk surface **68** to an outer disk surface **70**. The rotor disk **58** includes a plurality of slots **72** (e.g., dovetail slots, to name just one non-limiting example) arranged circumferentially around the axial centerline A. Each fan blade **60** includes a root **74** and an airfoil **76**.

Referring to FIG. **3**, each spacer **62** includes elongated body member **78** including a first spacer end **80** and a second spacer end (not shown). Each spacer **62** may be constructed from an elastically deformable material. In at least one embodiment, the elastically deformable material is selected from a group consisting of: a rigid elastic material, a compliant material, an elastomeric material, a viscoelastic composite material, a plastically crushable material, a thermoplastic material, a thermoset material, and a honeycomb structured material. For example, a rigid elastic material such as a carbon composite material (e.g., laminated, 3D woven carbon sheets, to name just one non-limiting example), a compliant material such as an elastomeric material (e.g., natural or synthetic rubber, to name just two non-limiting examples), a viscoelastic composite material (e.g., a para-aramid synthetic fiber (such as Kevlar®) material and epoxy, to name just one non-limiting example), a plastically crushable material such as a composite crushable core material (to name just one non-limiting example), a thermoplastic material (e.g., polyether ether ketone (PEEK), to name just one non-limiting embodiment), a thermoset material (e.g., vinyl ester bulk molding compound, to name just one non-limiting embodiment), and/or a honeycomb structured material, etc. may be used to construct each spacer **62**.

Each spacer **62** further includes a conduit **82**, including a conduit outer surface **84** and a conduit inner surface **86**, disposed within the elongated body member **78**. In at least one embodiment, the conduit **82** is positioned near one of either the first spacer end **80** or the second spacer end (not shown). It will be appreciated that a conduit **82** may be positioned at both the first spacer end **80** and the second spacer end (not shown) to allow access to the conduit **82** from either end. The conduit **82** is configured to cooperate with a suitable tool (not shown) for the safe removal of a spacer **62** in the disassembly of the fan blade **60** from the slot **72** (see FIG. **2**). In at least one embodiment, the conduit **82** is composed of a metallic material. For example, the conduit may be composed of aluminum, steel, or titanium to name a few non-limiting examples. In at least one embodiment, the conduit **82** includes a plurality of threads **88** disposed on the conduit outer surface **84**. The plurality of threads **88** disposed on the conduit outer surface **84** are configured to reduce the axial movement of the conduit **82** disposed within the elongated body member **78**. In at least one embodiment, the conduit **82** includes a plurality of threads **90** disposed on the conduit inner surface **86**. The plurality of threads **90** disposed on the conduit inner surface **86** increases the engagement of the suitable tool used to remove the spacer **62**. In at least one embodiment, the conduit is formed in a helical shape.

It will be appreciated that each spacer **62** may include a conduit **82** disposed within the elongated body member **78**, thus reducing the likelihood of breaking the spacer **62** during removal of the spacer **62** in the disassembly of the fan blade **60** from the slot **72**.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only certain embodiments have been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

What is claimed is:

1. A spacer for insertion in a slot in a fan rotor, the spacer comprising:

an elongated body member including a first spacer end and a second spacer end;

a conduit, including a conduit outer surface and a conduit inner surface, disposed within the elongated body member, wherein the conduit includes a plurality of threads disposed on the conduit inner surface, wherein the conduit includes a plurality of threads disposed on the conduit outer surface; and

wherein the elongated body member is composed of an elastically deformable material.

2. The spacer of claim **1**, wherein the conduit is positioned near one of either the first spacer end or the second spacer end.

3. The spacer of claim **1**, wherein the conduit is composed of a metallic material.

4. The spacer of claim **1**, wherein the conduit is formed in a helical shape.

5. The spacer of claim **1**, wherein the elastically deformable material is selected from a group consisting of: a rigid elastic material, a compliant material, an elastomeric material, a viscoelastic composite material, a plastically crushable material, a thermoplastic material, a thermoset material, and a honeycomb structured material.

6. A fan rotor comprising:

a disk including a plurality of slots in its periphery, each slot including a slot bottom surface;

a plurality of blades attached to the disk, each blade including a blade root engaged in a corresponding one of the plurality of slots;

an elongated spacer interposed between each of the blade root and the slot bottom surface of the corresponding one of the plurality of slots, wherein the elongated spacer includes a first spacer end and a second spacer end;

a conduit, including a conduit outer surface and a conduit inner surface, disposed within the elongated spacer, wherein the conduit includes a plurality of threads disposed on the conduit inner surface, wherein the conduit includes a plurality of threads disposed on the conduit outer surface; and

wherein the elongated spacer is composed of an elastically deformable material.

7. The fan rotor of claim **6**, wherein the conduit is positioned near one of either the first spacer end or the second spacer end.

8. The fan rotor of claim **7**, wherein the conduit is composed of a metallic material.

9. The fan rotor of claim **7**, wherein the conduit is formed in a helical shape.

10. The fan rotor of claim **7**, wherein the elastically deformable material is selected from a group consisting of: a rigid elastic material, a compliant material, an elastomeric material, a viscoelastic composite material, a plastically crushable material, a thermoplastic material, a thermoset material, and a honeycomb structured material.

11. A gas turbine engine comprising: a fan assembly comprising:

a disk including a plurality of slots in its periphery, each slot including a slot bottom surface;

a plurality of blades attached to the disk, each blade including a blade root engaged in a corresponding one of the plurality of slots; and

an elongated spacer interposed between each of the blade root and the slot bottom surface of the corresponding one of the plurality of slots, wherein the elongated spacer includes a first spacer end and a second spacer end;

a conduit, including a conduit outer surface and a conduit inner surface, disposed within the elongated spacer, wherein the conduit includes a plurality of threads disposed on the conduit inner surface, wherein the conduit includes a plurality of threads disposed on the conduit outer surface; and

wherein the elongated body member is composed of an elastically deformable material.

12. The gas turbine engine of claim **11**, wherein the conduit is positioned near one of either the first spacer end or the second spacer end.

13. The gas turbine engine of claim **11**, wherein the conduit is composed of a metallic material.

14. The gas turbine engine of claim **11**, wherein the conduit is formed in a helical shape.

15. The gas turbine engine of claim **11**, wherein the elastically deformable material is selected from a group consisting of: a rigid elastic material, a compliant material, an elastomeric material, a viscoelastic composite material, a plastically crushable material, a thermoplastic material, a thermoset material, and a honeycomb structured material.

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